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Analyzing On-Street Parking Demand in Yogyakarta, Indonesia

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Carolina Ajeng

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지도교수 김태형

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환경계획학과. 도시및지역계획학 전공

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위 원 장 김경민 (인)

부위원장 Quan, Steven Jige (인)

위 원 김태형 (인)

Abstract

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Carolina Ajeng

Urban and Regional Planning
Department of Environmental Planning
Graduate School of Environmental Studies
Seoul National University

On-street parking became a big issue in Yogyakarta city, Indonesia, because uncertain characteristics and many stacking data in it. This study aims to analyzing on-street parking demand and its characteristics by using GIS approach, field survey, and statistical approach. There were 34 street segments that used for on-street parking in area study. Identifying parking characteristics by Quickbird imagery just limited on parking angle and even not maximal yet. GIS technique was helped to extract parking angle and street length, and to calculate parking demand and its capacity. Meanwhile, field survey conducted for other parking characteristics. The highest parking demand was in St. Prof. Herman Yohanes, St. Urip Sumoharjo, St. Affandi, and St. Laksada Adisucipto which dominated by motorbike parked. They have bad parking condition because parking demand exceed its capacity. Regression

result shows that street length, parking volume, commercial land use, and health facility simultaneously have significant effect on parking demand. However, only street length which partially has significant effect on parking demand. It became the most important role in predicting parking demand with percentage effect of 70.6 %.

Keywords : on-street parking, parking demand, GIS
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1. INTRODUCTION

Background

Indonesia is a developing country with population of over 250 million in 2015 (World Bank, 2017). Private vehicles increase rapidly and plays main role in Indonesian population's mobility. That increase requires sufficient parking space and if it does not increase proportionately with the rate of transportation infrastructure development, it will lead to parking problems. Parking management are getting uncontrollable. Parking problems become big issues in many big cities in Indonesia, such as in Yogyakarta city, and it becomes underdeveloped transportation problem.

The increasing of private vehicles simultaneously causes the increasing of parking demand in Yogyakarta city. Most of resident use private transportation as transportation mode in the form of motorbike and personal car. According to the data from Department of Finance and Asset Management Revenue Yogyakarta (2014), the number of motor vehicles per year increased by about 14-16% for the last 5 years. In 2013, the number of motor vehicles in Yogyakarta Special Province (DIY – *Daerah Istimewa Yogyakarta*) reached 1,396,967 vehicle unit, an increase of approximately 15% since 2009. This growth is not comparable with the increase of road which was 2-5% per year. In Yogyakarta city, the number of motor vehicles increased rapidly from 2012 to 2015 and most of them are motorcycle. Figure 1 shows that the total number registered motor vehicles in Yogyakarta city has been drastically increasing since the official registration record has started. Whole of Yogyakarta city must have been getting worse at the same time, such as increasing air pollution, traffic congestion, and parking demand.

In Yogyakarta, there are not too many parking lots that can accommodate all vehicles parked that leads to on-street parking. Overload of parking leads to disruptions in traffic obstructions and blocked the traffic accesses. This condition makes decreasing of traffic safety, increasing air pollutions, disappearing public

space, and declining economic potential. General Directorate of Land Transportation (1998) regulates that parking area/lots must be provided for each land use which is about 1.5 – 2% of total floor area for regional trade and service. For office complex and settlements is 2 – 3 % of total floor area. By knowing the parking condition, the transportation problems caused by on-street parking can be minimized and the ideal parking management can be used as a reference in Yogyakarta city's parking management.

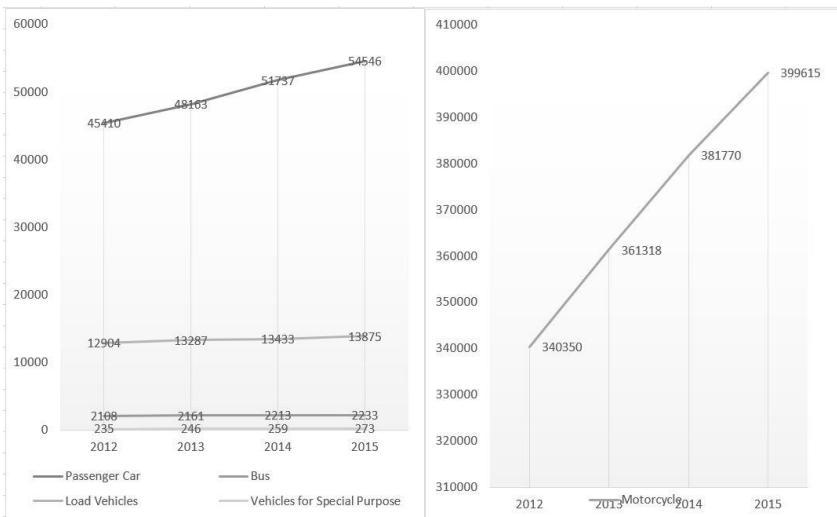


Figure 1. Trend Number of Motorized Vehicles in Yogyakarta City 2012 – 2015 (Source: Statistic of Yogyakarta City, 2016)

This study using parameters that aims to identify parking characteristics, such as land use, parking angle, road geometry, motor vehicles, parking volume, parking accumulation, and parking duration. Some parameters can be extracted from remote sensing imagery with high-spatial resolution such as QuickBird imagery. Meanwhile, field survey can be utilized to obtain other parameters. The type of motor vehicles is only limited to passenger car and motorcycle.

Gondokusuman district located in the center of Yogyakarta city, so the resident activity in this region is dense. The high number of social and economics facilities translates into the increase in parking demand. Parking area provided by

each land use is still not able to accommodate all the vehicles parked, hence causing on-street parking problems. This study aims to identify the number of parking demand in Gondokusuman district in Yogyakarta city to be the starting point for parking planning.

Statement of Problem

Parking management is an underdeveloped transportation subject. The number of vehicles increase rapidly and present massive problem in Indonesia's cities. Parking problems in Yogyakarta city being more complicated and should be resolved by applying the better concept of parking management. However, in fact, parking problems has grown into serious issue, which is due to urbanization urge, the rapid rate of vehicles growth, and pressure from motor vehicle manufactures. They are exacerbated by illegal parking problem because government regulations still not firmly against on-street parking. Another problem is traffic congestion because most of roads being narrower and used for street parking.

Generally, most of Yogyakarta's resident use private transportation because public transportation still not good enough then make them prefer use private vehicles which is more comfortable and safer. That condition simultaneously causes the increasing of parking demand. Meanwhile, the existing parking areas are no longer able to accommodate parking demand and leads to on-street parking. People behaviour who do not like to far-walking prefer parking on the street where is closer to their destination. Besides, there is no data on the number of parking demand which make parking management not maximal yet. The parking demand data is needed as the basis of parking planning and policy making. Those conditions make on-street parking problems became a big issue in Yogyakarta.

Bad parking management in Yogyakarta have made other transportation problems, such as traffic congestion, inhibiting traffic flow, traffic accidents, and others. The congestion point is common in St. Urip Sumoharjo because it has double on-street parking, parking for motorbike in one side and parking for personal car in

other, and even pedicabs parked in that area as well (Figure 2). Government of Yogyakarta city has been attempting to reduce traffic congestion by making the street into one way in St. Prof Herman Yohanes and St. Urip Sumoharjo. However, it has no much influence in it. Both of those streets still frequent of traffic congestion. Besides, parking overload often occurred by motorbike and utilized sidewalks to accommodate excess parking or make it into two lines of vehicles parking. This condition very seized the street width and decreasing sidewalks function. There were no road crossing signs made residents crossing the road carelessly and disrupt traffic flow. Besides, utilizing sidewalks for parking is another problem that occurred by bad parking management in Yogyakarta. Not only motorbike that utilize sidewalks for parking, but also some cars parking in the sidewalks, even there was signal to not parking. Besides, there were pedestrians who walked in street body because there was no more space in sidewalks. It was very dangerous for them because it likely an accident. In other hand, parker usually help to get-in and get-off vehicles parked carelessly so it dangerous to other passing rides and themselves (Figure 2).

Figure 2. Traffic congestion and parking violations by utilizing sidewalks

Most of parking area have not equipped by the parking marker and signs so it causes inconsistently on the value of parking demand. Parking signal was also unclear so many motorbike parking carelessly. Therefore, parking violations were still prevalent in area study. Even though most of the street segments have been banned to not parking, but there were still many vehicles parking in the forbidden

area.

Construction of urban facilities must be balanced by provision of parking facilities in each building. A good parking management in a city can be help in reducing other transportation problems. Parking policies and regulations should play a strong role in developing strategies to improve urban mobility. People culture on parking behaviour is difficult to change, but it can be conducted by good transportation planning. Ideal parking can be used as a basis for creating good parking management in Yogyakarta. Parking demand in Yogyakarta city is still high and not fulfilled. The lack of data of parking demand makes a big problem because parking demand will always increase. Therefore, this research is conducted to analyse on-street parking demand and its characteristics in Gondokusuman district, Yogyakarta city.

Research Question

This study aims to answer question about how big is the number of on-street parking demand in Gondokusuman district, Yogyakarta city in 2017 and the influence parking characteristics used in it. Furthermore, mapping, calculating, and analyse the parking condition in Yogyakarta will conducted based on the data obtained.

2. THEORETICAL BACKGROUND

Parking as Transportation Subject

Parking means temporary non-moving vehicles. Parking also means any vehicles that stop at certain places whether parked on parking area or to ride-on and ride-off goods or people (Abubakar, 1998). There are 2 kinds of parking, including on-street parking and off-street parking. On-street parking using part of road for parking that are public right (local streets or highways). Meanwhile, off-street

parking means parking lot provided specifically outside the existing road and has special entrance (paid parking system that have certain limits).

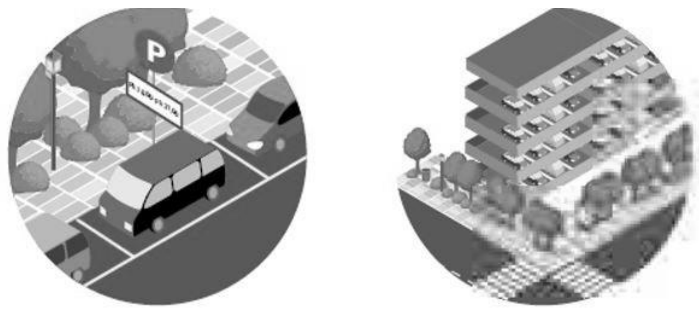


Figure 3. On-street parking (left) and off-street parking (right)
(Source: GIZ SUTIP, 2015)

The organization parking facility divided into three stages including development, operation, and maintenance. The organizers may be conducted by the government, agency law, and individual. The provision of on-street parking should cooperate with local government.

Figure 4. The concept of parking space unit
(Source: GIZ SUTIP, 2015)

Parking space unit (SRP – *Satuan Ruang Parkir*) means the size of an effective area for parking vehicle, including free space and wide-open doors. The determination of SRP relates to the technical design for parking supply (GIZ SUTIP, 2015). The dimensions and characteristic of each different vehicle make SRP design has variation according to parking characteristics which based on vehicle type.

Table 1. Parking Space Unit (SRP) for Each Vehicle

Type of Vehicle	Parking Space Unit (m)
1. Passenger car	
a. class I (doors not full open)	2,30 x 5,00
b. class II (doors full open)	2,50 x 5,00
c. class III (people with disabilities)	3,00 x 5,00
2. Bus/truck	3,40 x 12,50
3. Motorcycle	0,75 x 2,00

(Source: General Directorate of Land Transportation, 1998)

Parking Management

Parking management is strategies to encourage the use of more efficient parking facilities, to improve parking service quality, and to increase the design of parking facilities (VTPI, 2013). There are some regulations on parking management, including Law 22/2009-*Lalu Lintas Angkutan Jalan* (LLAJ) article 43 (clause 1 and clause 4) and article 44, Regional Regulation 5/99 DKI Jakarta on Parking in DKI Jakarta, and parking management by GIZ module 2C. Government Regulations of Indonesia no.32 / 2011 said that parking management is part of the Traffic Needs Management strategy to improve the efficiency and effectiveness of traffic users and control the movement of traffic on the road space by time restrictions, duration, price, quota, and parking location.

Several big cities in Indonesia have started implementing parking management and can be appointed as an example even though this step still partial. The results show that parking management is done by considering local conditions so that it can be effective. These cities are Palembang, Jakarta, Bogor, Bandung, Surakarta, and Sidoarjo (Figure 5). Among those big cities, Yogyakarta city is not included in the city that has implemented parker management system, so there are still many parking problems. This makes the author choose Yogyakarta city, especially Gondokusuman district, as an area study to calculate parking demand and to examine existing parking problems, especially focus on on-street parking.

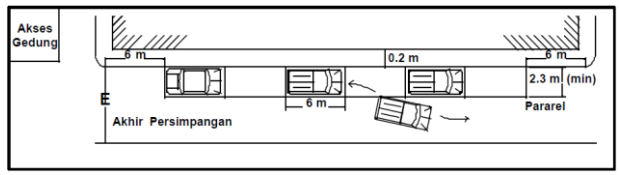
Figure 5. Map of Parking Management Implementation in Indonesia
(Source: GIZ SUTIP, 2015)

Parking Characteristics

Parking characteristic means the basic properties for assessing parking service and parking problems that occur in area study. On-street parking characteristics including street length, parking volume, parking accumulation, parking duration (time), parking angle, and parking capacity.

- *Street length*, means the length of the street that used for parking.
- *Parking Accumulation*, means total number of vehicles in a parking area at a certain time.
- *Parking Volume*, means the total number of vehicles that using parking facilities, usually calculated in parked vehicles in a day or during observation time.
- *Parking duration*, means the time span of parked vehicles in a parking area.
- *Parking angle*, on-street parking consists of parking with parallel system (0^0) and angular system with certain angle, including 30^0, 45^0, 60^0, and 90^0.

a. Parallel parking system (0^0)



b. Angular parking system

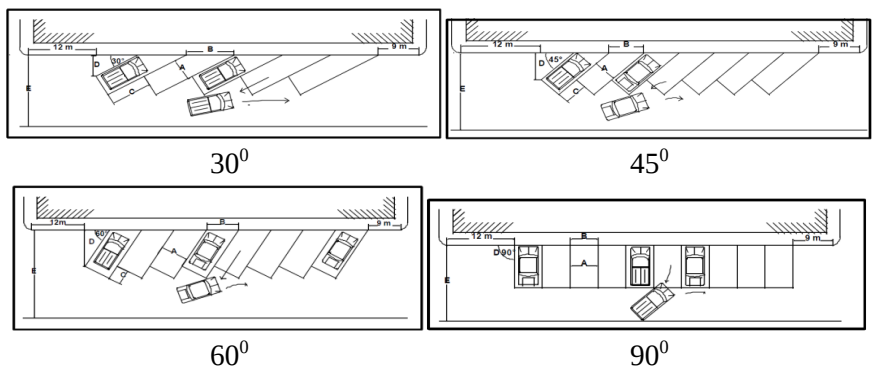


Figure 6. Parking angle system
(Source: General Directorate of Land Transportation, 1998)

❖ *Parking capacity*, means the maximum unit of vehicles parked in a parking area in certain time and certain condition. This value is fixed and calculated based on street length and parking angle. The calculation on parking capacity is based on the calculation from Department of Transportation Yogyakarta City, 2011.

3. LITERATURE REVIEW

Differences in this research from previous studies may be determined by the difference of one of some elements, such as location, method, and focus of study. Research on parking management has been done in many regions in the world. However, in Indonesia, particularly in Yogyakarta city, it is not too many, whereas there are still parking problems especially on-street parking. This research has

differences with previous studies and showed by title, purpose, location, method, and expected outcomes.

A study by Fauziati (2011) was a parking survey research based on remote sensing technique. Methods used are Quickbird interpretation, field survey, and descriptive analysis. Similarities with this study are location, Yogyakarta city, and satellite imagery type. Meanwhile, the differences are in the imagery recording year, research method, and parameters. The calculation of parking condition in this study is only focus on each segment of the street and not considering land use function, but determination road segments in the research is more detail based on block of land use function. The method in calculate parking demand is also different. Besides, this study didn't use statistical analysis in parking analysis.

Li and Guan (2011) have done their study which aims to utilize geospatial information technologies, such as GPS and GIS to improve the effectiveness and efficiency of parking space search. This study related to reduce gasoline consumption and GHG emission which caused by parking space searching. Daily data of low position of precision (PDOP) was collected by Trimble Planning software and GPS data was collected by field survey. So, generally data collecting in this study was done by field survey, not by high-resolution imagery view. Basically, this method can provide detail data because the area used was in big scale, but it needs more time, cost, and energy to collecting data. The result was also just show the geographic location of parking meters with their attributes in it. There is no in-depth analysis in UNL campus parking demand.

Levy and Benenson (2015) did a study which method used called PARKFIT, a method and software application to calculate spatial heterogeneity of the parking situation with the main tool used was GIS. This study aims to evaluate the fit between overnight parking demand and parking supply. This study didn't use high-resolution remote sensing imagery as a primary data but using high-resolution municipality GIS of Bat Yam as a secondary data. Parking capacity and parking demand were based on the availability layer and just focus on the residential overnight parking. This

study calculating parking condition using PARKFIT, but the research will be conducted by calculating from The Ministry of Transportation Indonesia. Besides, this study was just focus on residents' car, but the research will conduct in passenger car and motorbike.

Levy, Render, and Benenson (2015) did a study which use PARKAGENT model, as an ArcGIS application for parking search. Data used was secondary data in the term of layer. Limitation of parking development termed "maximum provision" codes were base to analyse parking search by supply-independent and parking demand. Generally, it was focus on parking search by driver, not focus on parking demand.

Based on previous studies, the authors want to do a research on parking subject which focus on on-street parking demand. Mapping unit used is street segment based on land use block function. The method used is quantitative method where the parameters obtained by Quickbird imagery interpretation by visually interpretable through digitization on a screen. Some parking parameters obtained by field surveys. The analysis of on-street parking is based on QuickBird imagery interpretation and field survey data as primary data. Besides, statistics analysis is conducted to know the influence parking characteristics on on-street parking demand in area study.

4. RESEARCH METHODOLOGY

This study using quantitative approach to map and to analyze parking demand and its characteristics in part of Yogyakarta city. The mapping unit is street segment which is decided by block of land use function. The methods used are QuickBird imagery interpretation by GIS, field survey, and statistics analysis. Imagery interpretation aims to extract geospatial information such as land use block and street segment. Those parameters derived from manually digitized on-screen on

Quickbird imagery 2014. GIS tool helps in extracting parking characteristics, such as parking angle, street length, land use, and other street geometries, and helps in calculating and in analyzing parking demand and its condition. Field survey by observation used to get information about other parking characteristics which cannot obtained from Quickbird interpretation or non-geospatial information, such as parking volume, parking duration, parking accumulation, and parking angle. Field survey is conducted for 10 hours observation. Observation is conducted by manually record of vehicles parked. Then statistics analysis is used to analyze the influence of parking characteristics on on-street parking demand in Gondokusuman district. It can be use as basis for policy making.

This study uses 2 kinds of data, including primary data and secondary data. Primary data such as QuickBird imagery Yogyakarta City in 2014 (geometrically corrected) and field survey data. Secondary data including data on the number of motor vehicle from Statistics of Yogyakarta 2016, Yogyakarta Master Plan 2015-2035, and administration map of Indonesia scale 1:25.000 sheet Yogyakarta City (1408-023) and Timoho (1408-224).

Description of Area Study

Yogyakarta city is the administrative capital of the Special Region of Yogyakarta (D.I.Yogyakarta) province which located in the central part of Java Island (Figure 7). In 2015, with a total area of 32.5 km² and a population of 412,704 people, Yogyakarta had a density of 12,698 people/km² (BPS – Statistics of Yogyakarta, 2016). Yogyakarta known as the city of education, the city of tourism, and the city of culture. Yogyakarta city holds a main role in regional development of the province. Gondokusuman District is one of 14 districts in Yogyakarta City which located in the northern part of Yogyakarta City. It has an area of 3.99 km^2 and located 3 km from downtown of Yogyakarta. More than 85 % land use in Gondokusuman are built-up area with dominantly low-rise building. This district has

the highest population in Yogyakarta or around 11.35 % of total population (BPS – Statistics of Yogyakarta, 2016).

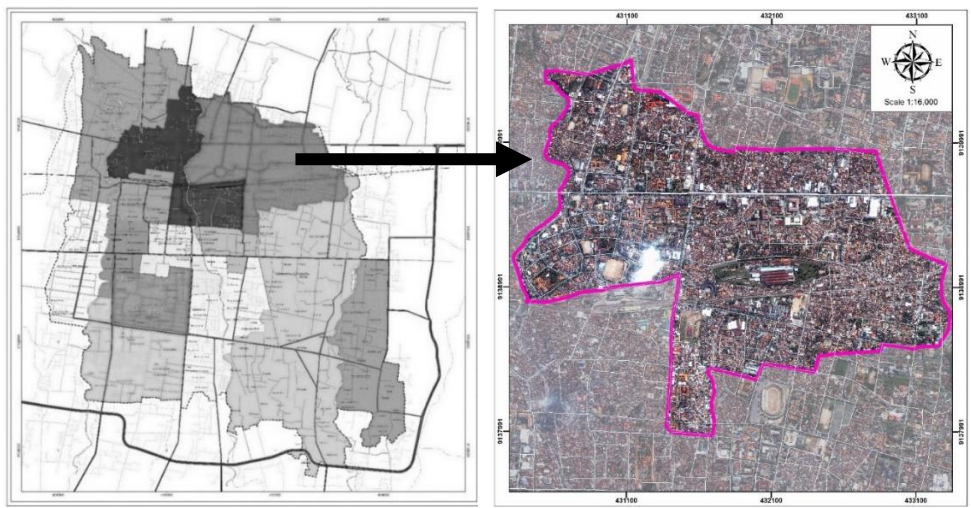


Figure 7. Administration Map of Yogyakarta City and Gondokusuman district

Vehicle ownership data can show an overview of parking demand which must be provided to accommodate vehicles. Figure 1 have shown data on the number of motor vehicles in Yogyakarta City in 2015. The increasing of vehicle ownership shows the purchasing ability of motor vehicle by the residents is higher and affect the increasing of parking demand. Based on that, Gondokusuman district which has complex problems in transportation sector is considered appropriate to do research on parking management.

Research Step

Primary data is the data obtained by field survey and interpretation of Quickbird imagery. Meanwhile, secondary data obtained by other parties without making measurements and field survey. It can be obtained from an agency or government.

Table 2. Data type and data source

No	Data	Primary Data		Secondary Data
		Quickbird, GIS	Field Survey	
1	Land use	√		√
2	Parking angle	√	√	
3	Parking volume, accumulation, duration		√	
4	Vehicle data, road data, administration boundary			√

This research using stratified random sampling as sampling method which is the sample selection determine randomly in each class of street segment. It is based on heterogeneous of class and has a stratification. Stratified means the level of road segment used for street parking is based on land use blocks. Meanwhile, the random is based on partially randomly selected street segment. It assumes that samples taken can represent each function of the street segment. Determination of the number of sample is specific and evenly on each class of road segment and according to the number of population in each class. It is expected that all road segment classes can be represented even though the scope is small, so it can be distributed evenly throughout the area study. It refers to the opinion from Congalton and Green (2008), where if the range of the study area is less than 404.7 ha and the number of class mapping units is less than 12 classes, the sample size is about 50 samples.

Field survey aims to obtain field data that used as parameters for calculating on-street parking demand and analyzing parking characteristics. Field survey is manual survey by observation parking volume, parking accumulation, parking duration and parking angle. It is conducted on each sample point on Friday in day time from 8 a.m. to 6 p.m. (10 hours).

Parking Condition Analysis

Parking condition analysis obtained by comparing the value of parking demand and parking capacity. Parking condition is sufficient if the number of parking capacity bigger than the number of parking demand. Parking capacity shows the maximum number of vehicles that can be accommodated in a parking area. On-street parking capacity is the ratio between the road length for parking area with the vehicle length for parking based on parking angle. The calculation is based on the data of road length and parking angle obtained by interpretation of Quickbird imagery and field survey, whether for motorcycle and car.

Table 3. Parking Capacity's Calculation

No	Vehicle Type	Parking Angle	Parking Capacity
1	Motorcycle	90º	L/0.75
2	Personal Car	0 º	L/5
		30 º	(L-0.88)/0.75
		45 º	(L-1.91)/3.25
		60 º	(L-1.84)/2.65
		90 º	L/2.3
3	Bus/Truck	0 º	L/12.5
		60 º	L/3.93

L: street length for parking
(Source: Department of Transportation Yogyakarta City, 2011)

Parking demand is calculated based on field survey data. On-street parking demand value is the maximum value of parking accumulation during observation time. Result calculation of parking demand can predict the amount of parking space that should be provided according to urban activity in area study.

Statistical Analysis

This study using multiple linear regression analysis method to know the

relationship between parking demand as dependent variable and parking characteristics as independent variables. It used to know whether parking characteristics influence on parking demand, both partially and simultaneously. Basically, parking characteristics is different between on-street parking and off-street parking. Off-street parking characteristics usually relates to building characteristics or people in each building, but on-street parking characteristics relates to street characteristics and land use characteristics along the street.

5. RESULTS AND DISCUSSION

On-street parking issues became a big issue in most big cities in Indonesia. Uncertain characteristics in it makes them become more complicated in transportation problems. Most of Yogyakarta city's resident use private transportation such as private car and motorbike for their mobility. Yogyakarta city just has public transportations in the form of city bus, car taxi (official and unofficial / *uber*), and motorbike taxi (unofficial / *ojek*). Service of public transportation still not maximal yet because it has bad quality and the limited of unit and route. Those conditions make them prefer using private vehicles for their safety and comfortable. Overview of parking demand can be seen on number of vehicles ownership in Yogyakarta. Basically, on-street parking rises caused by parking lots not able to accommodate the vehicles parking, so it uses street body for parking. However, there are several other factors that cause on-street parking, such as culture of local people and special event. Parking condition is related to the size of parking demand. However, in some area in Yogyakarta, especially in tourism area, parking condition were exacerbated by the problem of illegal parking, such as raising the parking fee by parker.

Land use is one of the factors that cause parking activity. Most of land use in area study were built-up area which dominantly by low rise building with the main

land use were commercial/trades and services. It usually impermanent trades in the form of street vendors. Residential land use was not including in this analysis because on-street parking identic with parking on the street side which not dominated by residential land use. Street segment was used as mapping unit and analysis unit which determined by the main land use function along street side. It estimates that parking demand for each type of land use may be different. However, not all land uses can trigger parking activity in the street. It depends on the attractiveness or main function for each land use. Besides, some street segments have been installed signal to not parking.

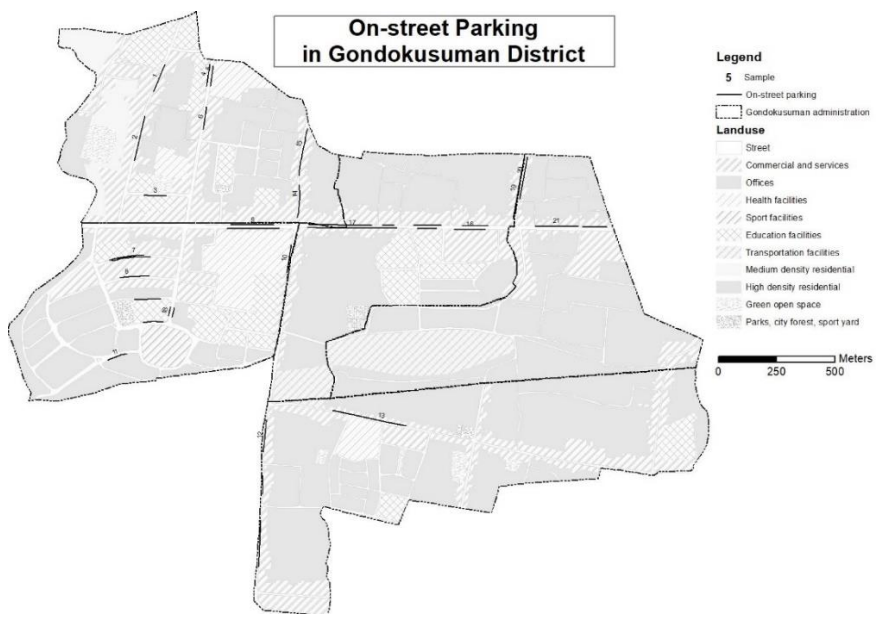


Figure 8. On-street parking activity in Gondokusuman district

Figure 8 shows the existing on-street parking in Gondokusuman district. There were 34 street segments used for parking, both parking for personal car and parking for motorbike. That map shows that most of parking activity located in commercial and services, hospitals, offices, and schools. There were some parking areas which located in the both sides of the street. Among of them, it took 21 samples

to do field survey and calculate parking demand. Observation have done to analyze parking demand and its characteristics for each sample taken.

There was several motorbike parking which not parallel to other vehicles because each street segment not only used for one type of vehicles parking, but consist of several types of vehicles parking which parked in the same parking area. Inequality of the type of vehicle parking causes inequality of parking unit. Therefore, equation into area m^2 was used to assist the parking calculation and statistical analysis. So, the unit of vehicles used not in vehicles unit but in area m^2 and equated based on the size for each vehicle.

GIS For On-Street Parking

Quickbird imagery helps to identify land use and several parking characteristics, such as street geometry and parking angle. However, parking angle that can be identified through Quickbird imagery just limited on personal car vehicle and even not all of them can be identified through Quickbird imagery. Motorbike vehicles cannot be identified by imagery because the maximum pixel is 60 cm x 60 cm, meanwhile the motorbike size just about 50 cm to 80 cm and the length about 175 cm. One pixel of satellite imagery contains from one color. So, it means that one motorbike just can be showed by one pixel. It was not enough to interpret and identify motorbike parking as an object. Besides, interpretation scale used should be small scale to make interpretation and identification object still consistent. Raster geometry by GIS can help to identify personal car parking angle from Quickbird imagery. It can be identified by looking at the line of parking marker in the street or by looking at the vehicles parked in the street. However, most of streets have not been equipped by parking marker line and covered by trees as well. So, it was difficult to extract parking angle through Quickbird imagery. Raster geometry cannot be effective because in some imagery pixels consist not only a unit of car but also other objects, such as trees or building shadow. Therefore, field survey was conducted to complete the data needed, that cannot be obtained by Quickbird

imagery.

Figure 9 shows the parking pattern at different angles for each segment from Quickbird interpretation and field survey data. Generally, parking angle used are parallel system (0º) and angular system (45º) for personal car, but for motorbike the parking angle used was same in 90º. Parking angle of 45º only located along St. Urip Sumoharjo.

Parking angle of 45º

Parking angle of 0º (parallel)

Figure 9. Parking angle from Quickbird imagery and field survey
(Source: Field survey, 2017)

Street length will be influence on the value of parking capacity. The bigger street length the bigger parking space can be provide for vehicles. Boundary point for each parking area plotted by GPS and input to GIS. Measuring by calculate geometry in GIS was conducted to know exact value of street length. Table 4 shows the length for each street segment and its parking capacity. Parking capacity shows

the maximum number of vehicles that can be provide for parking. Those value are fixed and used as standard to analyze parking condition. It based on calculating by The Ministry of Transportation of Yogyakarta City and obtained by comparing street length and parking angle. The bigger parking angle, the bigger parking capacity can be provided. Parking area which has parking angle of 45^{o} has bigger parking capacity than parking area with parking angle of 0^{o} (parallel). Such as in sample 17 in St. Urip Sumoharjo which has parking capacity bigger than another parking area which has similar size of street length, in sample 13. However, it will be effect on effectiveness of street width as well.

Table 4. Street Length and Its Parking Capacity

ID	Area	Street	Street Length (m)	Parking Angle	Parking Capacity (unit)	
					Motor bike	Car
1	ELS	St. C Simanjuntak	124,6	0^{o}	166	25
2	South ELS	St. C Simanjuntak	195,24	0^{o}	260	39
3	JHS 8	St. Kahar Muzakir	97,11	0^{o}	129	19
4	JHS 1	St. Cikditiro	94,71	0^{o}	126	19
5	Pantirapih	St. Cikditiro	87,38	0^{o}	117	17
6	South Pantirapih	St. Cikditiro	97,43	0^{o}	130	19
7	SHS STECE	St. Sabirin	151,06	0^{o}	201	30
8	South SHS STECE	St. Supadi	127,13	0^{o}	170	25
9	NOVOTEL	St. Jend Sudirman	186,26	0^{o}	248	37
10	Bethesda	St. Dr. Wahidin	120,4	0^{o}	161	24
11	LEGEND Café	St. Abubakar Ali	88,61	0^{o}	118	18
12	MUTIARA	St. Dr. Sutomo	139,44	0^{o}	186	28
13	KEMENDAGRI	St. Argolubang	320,69	0^{o}	428	64
14	GALERIA mall 1	St. Prof. Herman Yohanes	142,69	0^{o}	190	29
15	GALERIA mall 2	St. Prof. Herman Yohanes	205,06	0^{o}	273	41
16	XXI	St. Urip Sumoharjo	134,44	0^{o}	179	41
17	GARDENA	St. Urip Sumoharjo	384,74	45^{o}	513	77
18	SHS 3	St. Suroto	40,87	0^{o}	54	8
19	West AFFANDI	St. Affandi	255,16	0^{o}	340	51
20	East AFFANDI	St. Affandi	185,22	0^{o}	247	37
21	TOKO EMAS	St. Laksada Adisucipto	184,64	0^{o}	246	37

Parking Characteristics

Field survey was done on Friday for 10 hours from 10 a.m. to 6 p.m. because it was expected to represent the maximum parking demand in a week. Besides, field survey data also provide information about the type of vehicles parking and other parking characteristics such as parking duration, parking volume, parking angle, and others for each street segment.

a. Parking Volume

Parking volume shows the total unit of vehicles parked in each street segment in a day with the interval of observation was per hour. Figure 10 shows that the highest volume in a day was in sample 21 in St. Laksada Adisucipto with the total volume of personal car 111 vehicles and motorbike 275 vehicles. Both personal car and motorbike parking together in this parking area and it was also the main way to the Yogyakarta International Airport (Adisucipto Airport), so the traffic was quite crowded and frequent to traffic congestion, especially in the street segments that have double side parking.

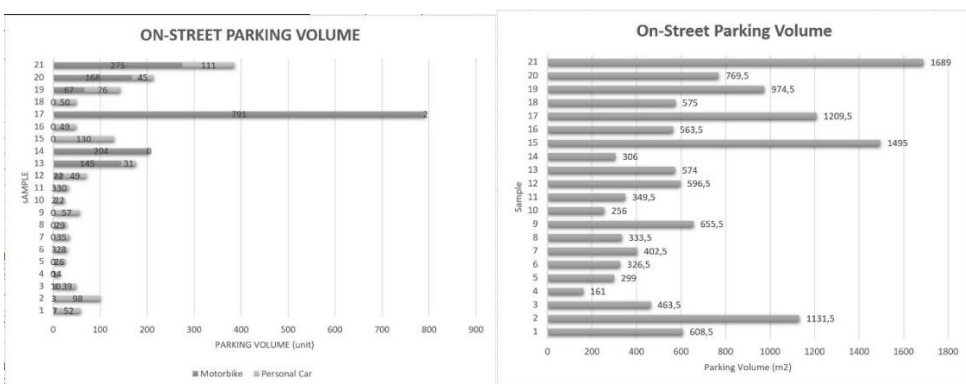


Figure 10. On-street parking volume

The value of parking volume cannot be used to indicate parking demand because it just shows the number of vehicles parked in a day. Motorbike has developed into main transportation mode with very large composition in Indonesia's cities, such as in Yogyakarta. The result indicate that most vehicles parked were

motorbike. Sample 17 shows that during observation time (10 hours), there were 791 motorbikes parked in that street segment. That number was big enough and shows overload parking demand. It was frequent to make parking area into two lines of parking that cause the street being narrower and most likely to traffic congestion. The characteristics of motorbike parking was different thus allowing raises problem in providing parking capacity.

b. Parking Duration

Parking duration for each street segment was generally different depends on the land use type. Parking peak hour for each land use has variance as well according to the parking demand by residents. However, the result shows that the type of land use has no influence on parking duration. Most of land use has on-street parking duration less than 1 hour. Only in some land uses that has variance on parking duration. Movie theatre or cinema in St. Prof. Urip Sumoharjo has parking duration from 1 hour to 3 hours because the length of time movie is around 2 hours (Figure 11).

Market and trades have average of parking duration less than 1 hour. Same land use has different parking duration as well. Stores or trades in St. Urip Sumoharjo has variance of parking duration from 1 hour to 2 hours per vehicles parked. The detail information for each land use is needed to know the characteristics which allows influence on parking duration. Parking duration by residents who worked in those land uses will be different with parking duration by customers in those trades. Other examples in hotel and hospital in St. Jend. Sudirman. Generally, people use parking facility at least 2 hours for parking, especially for hotels. However, more than 60% vehicles parking less than 1 hour. Most of vehicles type in NOVOTEL hotel were car taxi which parking just for drop-in, drop-out, or waiting the passengers in front of hotel. Therefore, those vehicles will not be parking for long time. Most of hotel's visitors and workers which bring their own vehicles usually already parking in the parking lots inside building. On-street parking have uncertain characteristics.

So, it is possible that on-street parking user can come from various land users and various purpose.

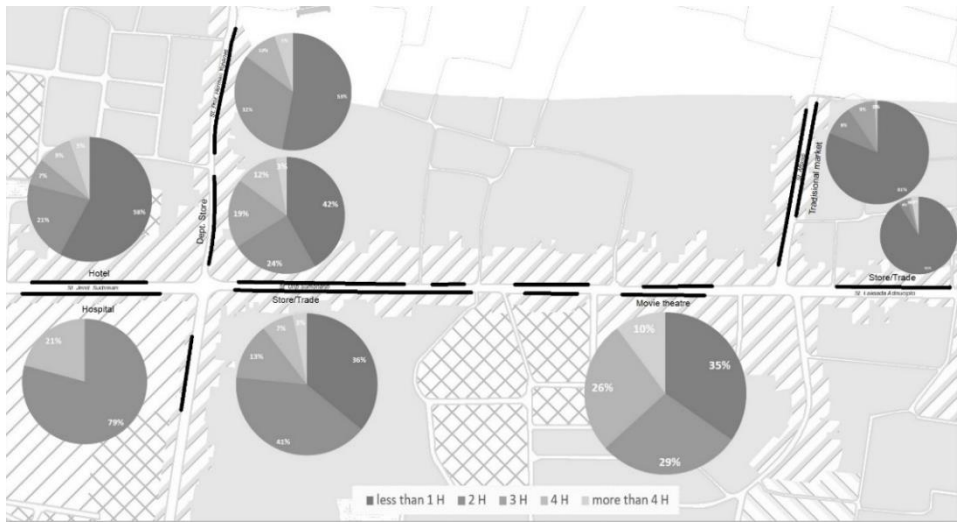


Figure 11. Parking duration in different land use type

Statistical model shows that only 34.2 % variance of parking duration can be explained by the changing of parking characteristics used, such as health facilities, commercial land use, parking volume, and street length. Meanwhile, the remaining of 65.8 % can be explained by other factors outside regression model used, such as parking purpose and parking users. Besides, those independent variables simultaneously have no significant effect on parking duration, because with the significant level of 95% ($\alpha = 0.05$) then significant value is more than 0.05. Other result from T test shows that parking characteristics used partially has no influence on parking duration. Each variable has significant value more than 0.05, so variables used have no significant effect on parking duration.

Even though they have no influence on parking duration, both simultaneously and partially, the commercial land use and street length were the strongest variable on parking duration. Beta coefficient of commercial land use was 0.607 then means that it has the percentage effect of 60.7 % in parking duration. This

value was the biggest value, so the commercial land use was the strongest variable in this model. It became most important variable in predicting parking duration. Street length also has important role with beta coefficient value of 0.456 or has percentage effect of 45.6% in parking duration. Meanwhile, the other independent variables have small effect on parking duration. Beside commercial land use and street length, it must consider other factors that can influence on parking duration, such as people behavior, visitors, and other social factors.

Table 5. Statistical model of parking duration

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.585[a]	.342	.177	18.75316	1.818

a. Predictors: (Constant), X4 (land use: health), X1 (parking volume), X2 (street length), X3 (land use: commercial)
b. Dependent Variable: Y2 (parking duration)

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2920.467	4	730.117	2.076	.132[b]
	Residual	5626.895	16	351.681		
	Total	8547.362	20			

a. Dependent Variable: Y2 (parking duration)

b. Predictors: (Constant), X4 (land use: health), X1 (parking volume), X2 (street length), X3 (land use: commercial)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	73.594	11.806		6.234	.000		
	X1 (parking volume)	-.025	.014	-.501	-1.781	.094	.519	1.925
	X2 (street length)	.116	.065	.456	1.778	.094	.624	1.602

	X3 (land use: commercial)	24.746	11.738	.607	2.108	.051	.496	2.015
	X4 (land use: health)	9.445	13.018	.184	.726	.479	.641	1.560

a. Dependent Variable: Y2 (parking duration)

Inadequate on-parking management in area study can also be shown with the same parking price for each variance of parking fee, i.e. IDR 1,000 for motorbike and IDR 2,000 for personal car. Both field survey analysis and statistical analysis have shown that other parking characteristics, especially land use, has no influence on parking duration. Other social characteristics is needed to know the factors that can be influence on parking duration, such as local culture.

c. Parking Accumulation

Parking accumulation shows the average of parking demand per hour for each street segments. Both motorbike and personal car has the highest parking accumulation at 10:00 a.m. It generally dominated by visitors in a shops or trades which is operational hours of a public services is around 10:00 a.m. Parking accumulation during day time was not too high because these hours are office hours, so the parking turnover not too high either. Then, the highest parking accumulation in a day can be indicated as parking demand.

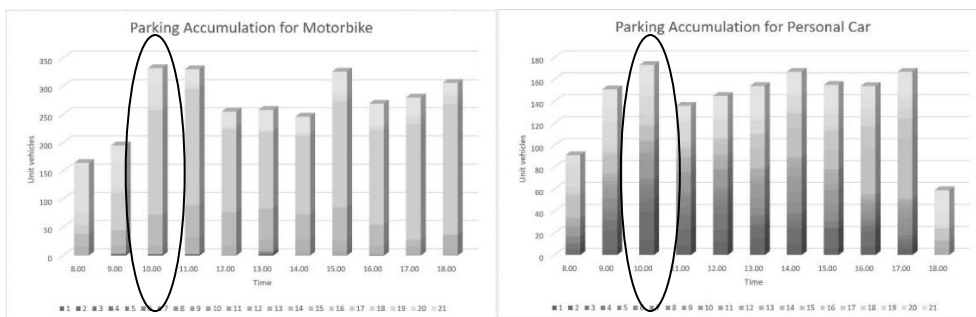


Figure 12. On-street parking accumulation, both motorbike and personal car

Parking Demand

On-street parking demand calculated by the highest parking accumulation during observation time. That value can show the maximum of parking demand in a day. Figure 14 shows parking demand for each street segment in the form of area unit (m^2) because it aims to equalize vehicles unit whereas they are parking together in same parking area.

The highest parking demand was in parking area which dominated by motorbike parked, such as in St. Prof. Herman Yohanes, St. Urip Sumoharjo, St. Affandi, and St. Laksada Adisucipto. Those street segments have parking demand 447 m^2 to 2,657 m^2 or around 231 units of motorbike parked in an hour. Most of those street segments just have capacity half of its demand. The high parking demand on these motorbike vehicles often leads to parking violations by utilizing other street body of sidewalks for parking.

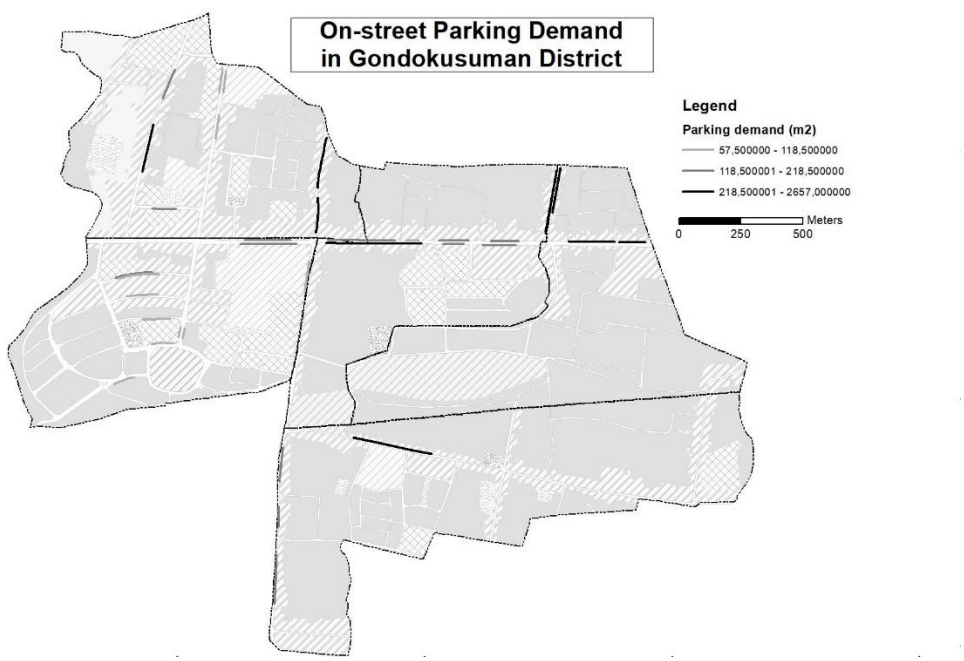


Figure 13. Map of On-Street Parking Demand in Gondokusuman District

Statistical analysis by multiple linear regression was conducted to know the influence of some of parking characteristics on parking demand. Basically, on-street parking and off-street parking have same characteristics. Parking characteristics by Indonesian General Directorate of Land Transportation, 1998, are parking volume, parking duration, parking accumulation, parking turns over, and parking index. Some studies on off-street parking usually add information about building characteristics, such as land area, number of floor, floor area, number of workers or visitors, and number of parking machine. However, it is different with on-street parking phenomenon which has more complicated condition because basically on-street parking is unplanning parking system. Some studies add other information about street characteristics, such as street width, street length, land use type, and land use area. This study uses parameters based on primary data by field survey and secondary data by GIS measurement, such as land use (commercial and health facilities), parking volume, and street length. Originally, those land uses were categorized into four groups, including commercial and service, office, health facilities, and educational facilities. This study combined office and educational facilities into one and put it as the base category. So, the variables used are commercial land use (dummy 1) and health facilities (dummy 2).

R Square value on model summary shows that 61.3 % variance of on-street parking demand can be explained by the changing of parking characteristics used. Meanwhile, the remaining of 38,7 % can be explained by other factors outside regression model used, such as people behavior on parking or local culture. Indonesian people known as people who do not like to far-walking because of security issues, air pollution issues, sidewalks issues, and others. Those condition make them prefer parking where is closer to their destination. Most of parking lots usually located far away, so they choose to be parking on the street which closer and cheaper. Those factors were not including in regression model, but it can be used to considering other factors that has possibility effect on parking demand.

Table 6. Statistical model of parking demand

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.783[a]	.613	.516	404.47240	2.213

a. Predictors: (Constant), X4 (land use: health), X1 (parking volume), X2 (street length), X3 (land use: commercial)

b. Dependent Variable: Y1 (parking demand)

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4140219.268	4	1035054.817	6.327	.003[b]
	Residual	2617566.803	16	163597.925		
	Total	6757786.071	20			

a. Dependent Variable: Y1 (parking demand)

b. Predictors: (Constant), X4 (land use: health), X1 (parking volume), X2 (street length), X3 (land use: commercial)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-597.779	254.628		-2.348	.032		
	X1 (parking volume)	.126	.300	.091	.421	.679	.519	1.925
	X2 (street length)	5.039	1.405	.706	3.585	.002	.624	1.602
	X3 (land use: commercial)	156.221	253.178	.136	.617	.546	.496	2.015
	X4 (land use: health)	181.649	280.772	.126	.647	.527	.641	1.560

a. Dependent Variable: Y1 (parking demand)

Simultaneous test (F test) shows that independent variables have significant value of 0.03. With the significant level of 95% ($\alpha = 0.05$), so independent variables simultaneously have a significant effect on parking demand. Meanwhile, partially from T test result, only street length which has significant effect on parking demand

with the significant value is 0.02. It is bigger than 0.05 as significant level, so street length partially influences on parking demand. The bigger street length, the bigger parking capacity that can be provided and allowing for increasing parking demand as well. Sample 17 in St. Urip Sumoharjo has the highest street length for parking and has the high parking demand as well. Land use partially has no effects on parking demand because same land use type has different value of parking demand. Therefore, land use function cannot be used as a benchmark to know the value of on-street parking demand.

Among of four independent variables, street length turned out to be significant at the 98% confidence level. It has most significant effect on parking demand. Street length has beta coefficient of 0.706, so street length has the percentage effect of 70.6% on parking demand. This value was the biggest value among other independent variables, so street length was the strongest variable in this model and the most important variable in predicting parking demand. It has main role in policy making as well because street length has the highest hierarchy in predicting the value of on-street parking demand. Meanwhile, other independent variables have small effect on parking demand with the percentage effect less than 15% each. Parking volume, commercial land use, and health facilities has presentation effect of 9.1%, 13.6%, and 12.6% on parking demand.

Parking supply-demand mismatch occurred because imbalance between parking demand and parking capacity. Supply-demand mismatch in off-street parking phenomenon will cause on-street parking because the vehicles failed to park in parking lots, so they utilized street body for parking. However, in on-street parking, if parking demand bigger than its capacity, so it can cause other transportation problems. Parking condition for each street segment can be seen by comparison between parking demand and parking capacity in area study (Figure 14). There were 6 street segments which have parking supply-demand mismatch, then they indicated have bad condition on on-street parking. Some street segments have parking demand twice bigger than the limit of parking capacity. Some problems occur caused by this

condition, such as traffic congestion and other parking violations. Generally, supply-demand mismatch only occurred on motorbike parking. This was rare occur on personal car because when the parking area is full, then they will try to find another parking space to park and not force to park. The excess parking usually utilizes the street body or sidewalk for parking which not included in field survey observation. It just limited on parking along street body, not in sidewalks. This problem was usually specific on motorbike parking.

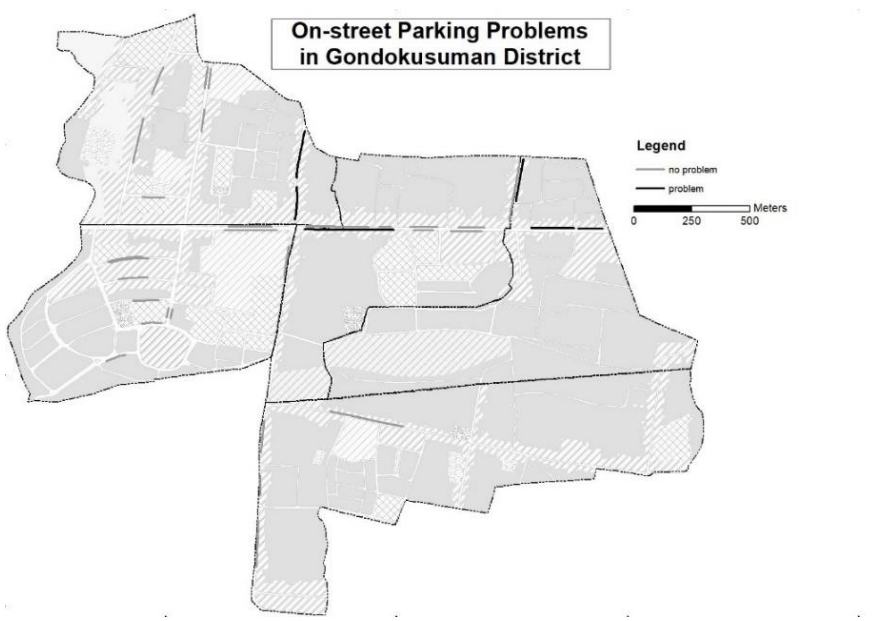


Figure 14. Map of On-Street Parking Problems in Gondokusuman District

Parking Policy

Number of parking demand and its statistical analysis can be used as basis in policy making. Street segments which have high parking demand or bad condition of parking should get priority in policy making. Statistical result shows that street length was the most important variable which influence on parking demand. This strongest variable has the highest hierarchy of urgency, so it should take precedence

in policy making. Supply-demand mismatch can be controlled by considering street length which was influence on parking capacity as well. Street length cannot be increased for parking, but it can be overcome by considering others which related to, such as parking angle. The short-term solution to do is to change the parking position by change parking angle from 45° to 0° (parallel), but it just specific for car parking (Figure 16). Some areas have implemented this scenario and has tendency of successful. This scenario automatically will reduce parking capacity about 40% to 50%, but it more effective to reduce other transportation problems which caused by on-street parking, especially traffic congestion because the street will become wider and accelerate traffic flow. Angular parking provides drivers feel comfortable than parallel system (0^0) because it requires less maneuvering to get in and get out of the parking lot, but this system more likely to cause accidents and narrowing of road width. Angular pattern also need less space than parallel parking in the term of width and length of vehicles parking.

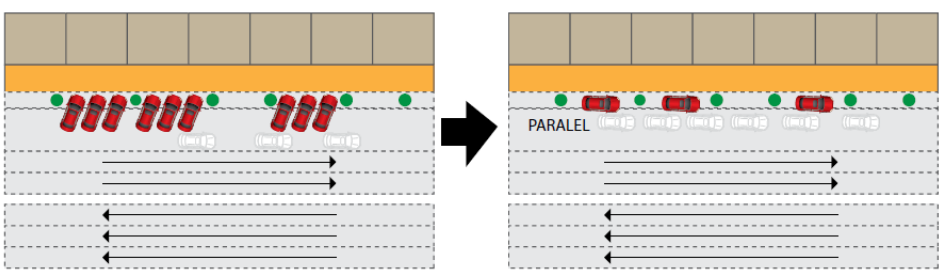


Figure 15. Scenario for changing parking angle
(Source: GIZ SUTIP, 2015)

In addressing parking problems, the government of Yogyakarta city divided several streets into several regions based on parking fees, especially for street which has high parking demand. It divides based on tourism area and commercial area into 4 regions. It aims to not only to increase local revenues but also to limit the use of parking area on certain street segments. The majority of Yogyakarta population use motorbike as main transportation because mostly the geometry of street network in Yogyakarta is grid with narrow alley variation that only motorbike vehicles pass

through. Therefore, most of on-street parking problems came from motorbike parking. Another scenario that can be applied is to utilize other street segments that have not been used to accommodate excess motorbike parking. Besides, the making of parking marker line for motorbike can be applied to limit parking overload. Parking behavior by residents is difficult to change, but it can be conducted by applying good parking management and parking policy to raise their awareness for parking.

6. CONCLUSION

On-street parking issue was undeveloped transportation problems in Yogyakarta city because it has unplanned transportation system and has uncertain characteristics in it. In area study, there were 34 street segments that used for on-street parking. There were some difficulties in interpreting parking characteristics through Quickbird imagery, especially for parking angle because most of parking area was not equipped by parking marker line and they were covered by trees. Identified parking angle just limited on personal car. Meanwhile, motorbike cannot be identified by imagery because the object was too small and not match with imagery pixel size. Identified parking angle by raster geometry from GIS was also not significant enough. Field survey was conducted and shows that most of parking angle for car was parallel (0^o), and only in St. Urip Sumoharjo which has parking angle of 45^o. Otherwise, parking angle for motorbike was default in 90^o.

GIS technique was much help to measure street length for parking and to calculate parking capacity and parking demand. The bigger street length and parking angle used for parking then the bigger parking capacity that can provided. The highest parking accumulation was at 10:00. Another result shows that land use has no influence of parking duration. Most of parking duration were less than an hour and just in several land uses which has variance of parking duration, such as movie

theatre which has parking duration of 2 to 3 hours. Statistical result also shows that street length, parking volume, commercial land use, and health facilities has no influence in parking duration, both partially and simultaneously. So, it is possible that on-street parking user can come from various land users and various purpose. It can be influenced by other factors outside the model such as people behavior and local culture.

The highest parking demand was in St. Prof. Herman Yohanes, St. Urip Sumoharjo, St. Affandi, and St. Laksada Adisucipto which dominated by motorbike parked. Bad condition of on-street parking was occurred in those street segments because parking demand was bigger than its capacity. Those streets most likely have parking demand double than the existing capacity. Utilizing sidewalks to parked occurred because parking capacity cannot fulfil the demand, and usually it just specific on motorbike, such as in St. Prof. Herman Yohanes. Traffic congestion most likely occurred in St. Urip Sumoharjo because it has double side on-street parking. In most of parking area were consist of different types of vehicles, such as motorbike, personal car, and even pedicabs which parked in the same parking area. There was no specific on-street parking space for pedicabs or bicycles in area study, so they usually can be parking anywhere. This inequality causes inequality of parking unit, unit equations were conducted to assist the parking calculation and analysis.

This study examines the effect of on-street parking characteristics on the value of parking demand in Yogyakarta city. The statistic model shows 61.3 % variance of parking demand can be explained by the changing of parking characteristics used and the remaining of it can come from other factors outside model. Parking volume, street length, commercial land use, and health facilities simultaneously have a significant effect on parking demand. However, partially, only street length which has significant effect on it. Street length was the most important variable in predicting parking demand with percentage effect of 70.6 %. The other independent variables only have percentage effect less than 15 % each. The highest proportion of street length can be used to considering urgency in policy making.

Street length can be reduced to minimized parking demand, but it should be considered by looking for other street geometries related, such as parking angle.

Parking phenomenon specifically related to the heterogeneity of the parking condition in the term of parking demand and capacity, and human behavior on other hand. In these case, GIS approach can be used as a tool to know geospatial knowledge of the parking phenomenon. To conclude, the results on the number of parking demand in area study may serve as a starting point for developing parking management and planning. Besides, it can be basis of policy making of on-street parking. The good parking planning and parking policy can raise the awareness for parking by residents.

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Abstract (in Korean)

불확실한 특성과 그것과 관련된 쌓인 데이터 때문애 노상주차(路上駐車)는 인도네시아 족자카르타에사 큰 이슈가 된다. 본 연구의 목적은 지리정보시스템 접근 방법과 현장조사와 통계적 겁근 방법을 통해, 노상주차(路上駐車) 수요와 그에 대한 특성을 분석하고자 한다. 본 연구의 지역연구는 노상주차(路上駐車)를 위한 34 개 구역을 분석하는 것이다. 최대치도 아니면서 제한되어 있는 주차 각도 퀵버드 이미지를 통해 주차 특성을 파악하는 것이다. 지도정보시스템 기술은 주차 각도와 거리 길이를 추출하고 주차 수요와 그 용량을 계산하는 데 도음을 주면서, 현장조사는 다른 주차 특성을 지휘한다. 제일 높은 주차 수요는 St. Prof. Herman Yohanes, St. Urip Sumoharjo, St. Affandi, 그리고 St. Laksada Adisucipto에 있는데 대부분 오토바이 주차였으며, 주차량 초과했기 때문애 주차 상태가 좋지 않다, 리그레션 결과에 따르면 거리 길이, 주차량, 상업적 토지 이용과 보건 시설은 동시에 주차 수요에 상당한 영향을 미친다. 하지만, 그중에 거리 길이만 부분적으로 주차 수요에 중대한 영향을 미친다. 그것은 70.6% 비율 효과의 주차 수요를 예측하는데에 있어서 가장 중요한 역할을 했다.

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